

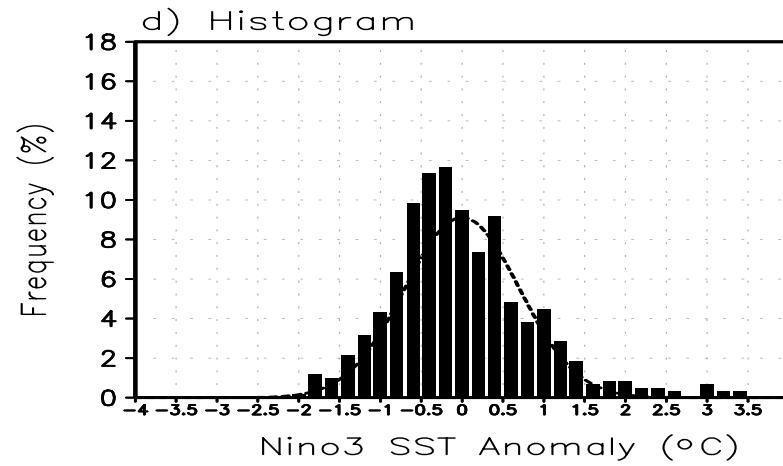
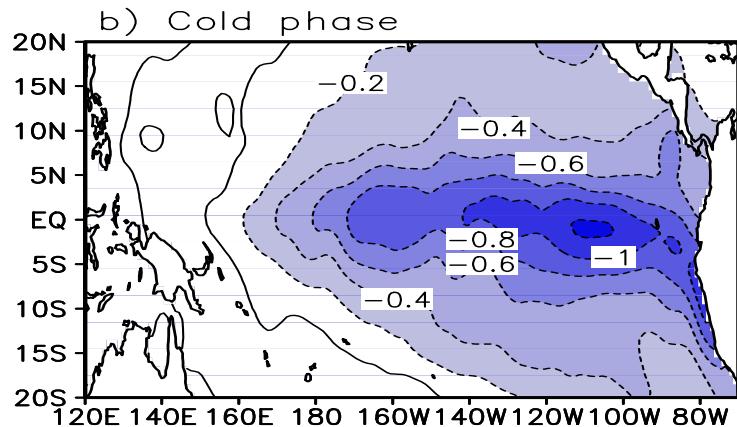
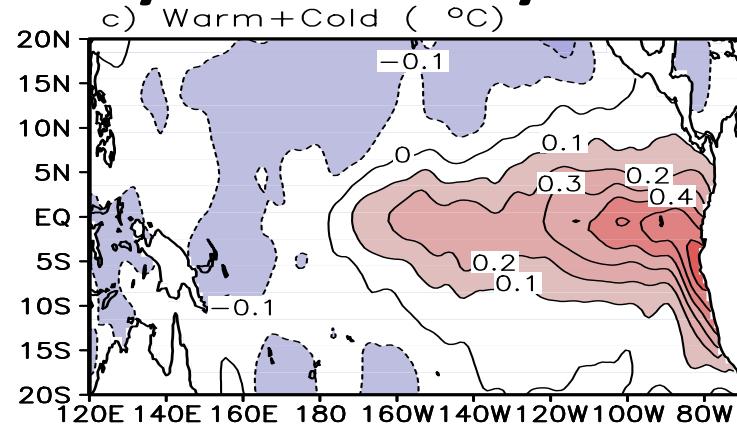
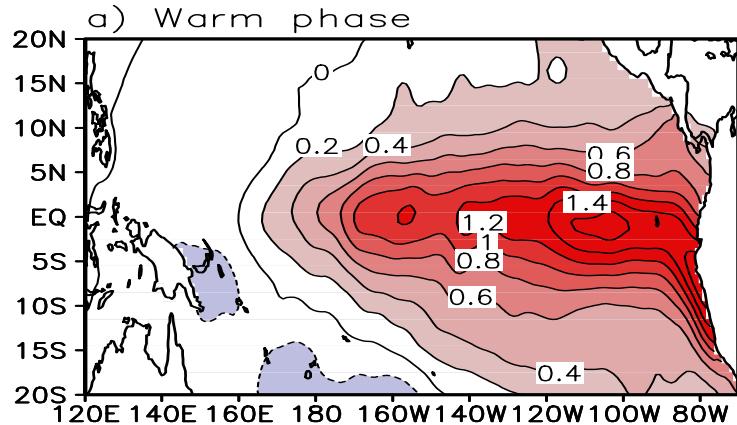
Understanding the Causes of ENSO Asymmetry Using CMIP5 Runs

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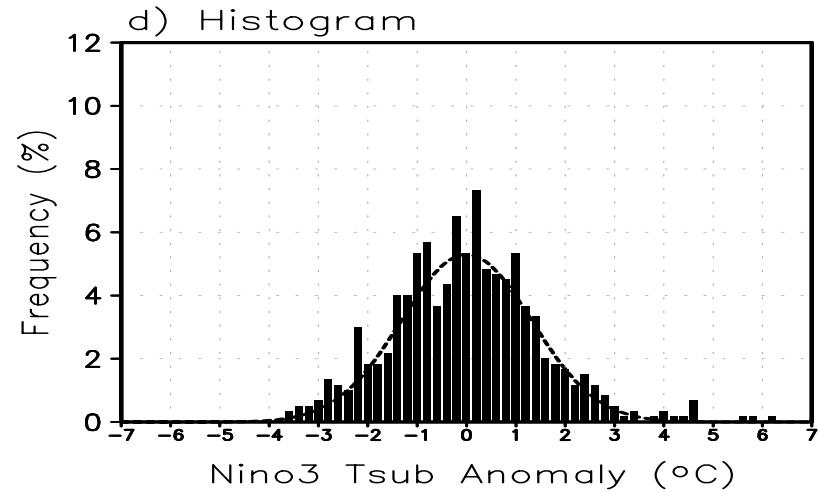
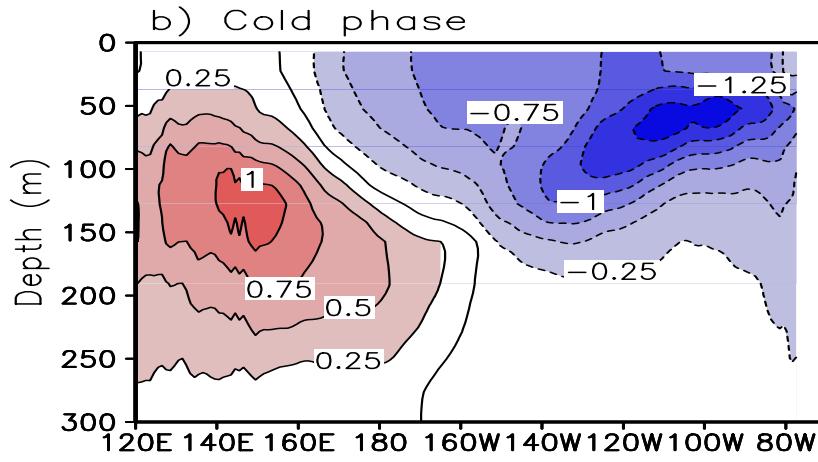
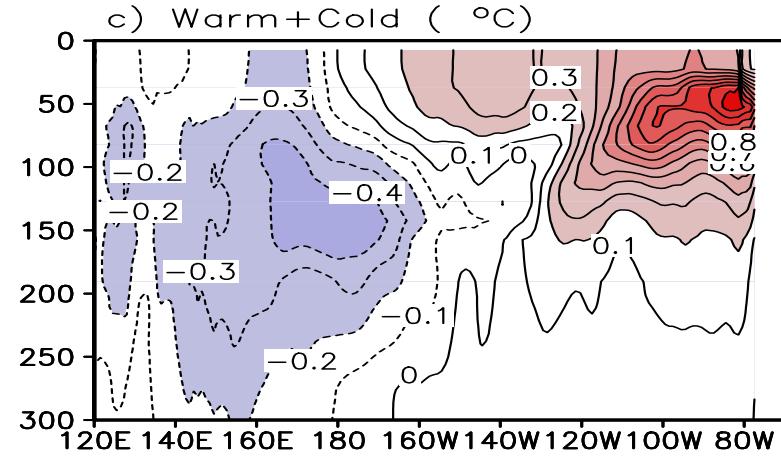
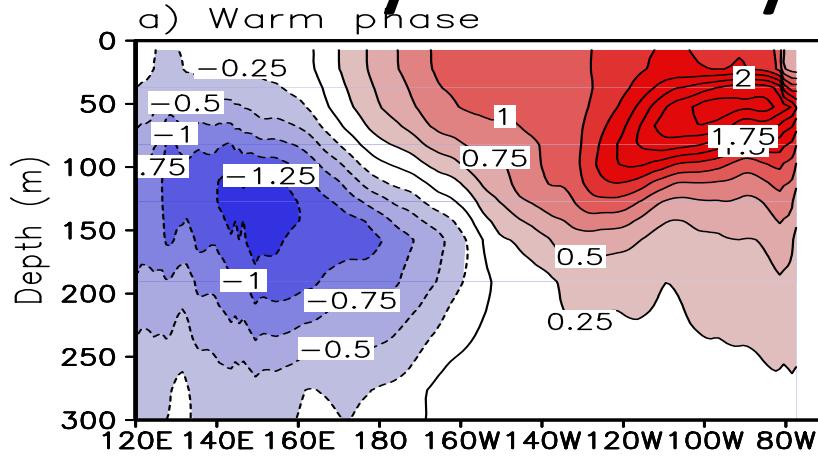
NOAA MAPP webinar
May 2, 2012

What is ENSO asymmetry?



- also as referred in some other studies, the residual of ENSO
(Rodgers et al. 2004; Schopf and Burgman 2006)
- fundamental property of ENSO
- larger magnitude during warm phase in contrast to cold phase
(Burgers and Stephenson 1999)

Asymmetry in subsurface



There is a positive asymmetry of subsurface temperature of 1°C around 75-m depth over the eastern Pacific. The observed Niño-3 subsurface temperature anomalies are skewed to the positive values (dashed line is normal distribution) and the maximum positive anomalies can reach more than 6°C . (Zhang et al. 2009)

Why it is important to evaluate ENSO asymmetry ?

**1) Rectification effect of ENSO events into the mean
(Sun and Zhang 2006; Schopf and Burgman 2006,
Sun 2010).**

**2) decadal variability in the tropics and beyond
(Rodgers et al. 2004; Sun and Yu 2009, Liang et al.
2011).**

Research Objective

By the analysis of previous NCAR models (CCSM1, 2, 3, and 3+NR), Zhang et al. (2009) showed that 1) All models underestimate the ENSO asymmetry, but CCSM3+NR with Neale and Richter scheme has significant improvements over the earlier versions. 2) An enhanced convection over the eastern Pacific during warm phase of ENSO appears to be the cause for the improvement.

Purpose of this study:

- Evaluate ENSO asymmetry in CMIP5 including its surface and subsurface signatures.
- Test the hypothesis developed from the previous analysis of NCAR models against the results from CMIP5 models.
- Understand the effects of model resolution on the simulation of ENSO asymmetry.

Methodology and data

1) Skewness (Burgers and Stephenson 1999)

**2) Asymmetry (variance weighted skewness) analysis
(An et al. 2005)**

Why? The definition of asymmetry (variance weighted skewness) can avoid the problem in the definition of skewness that small variance can cause larger skewness. The asymmetry results are more consistent with the composite analysis.

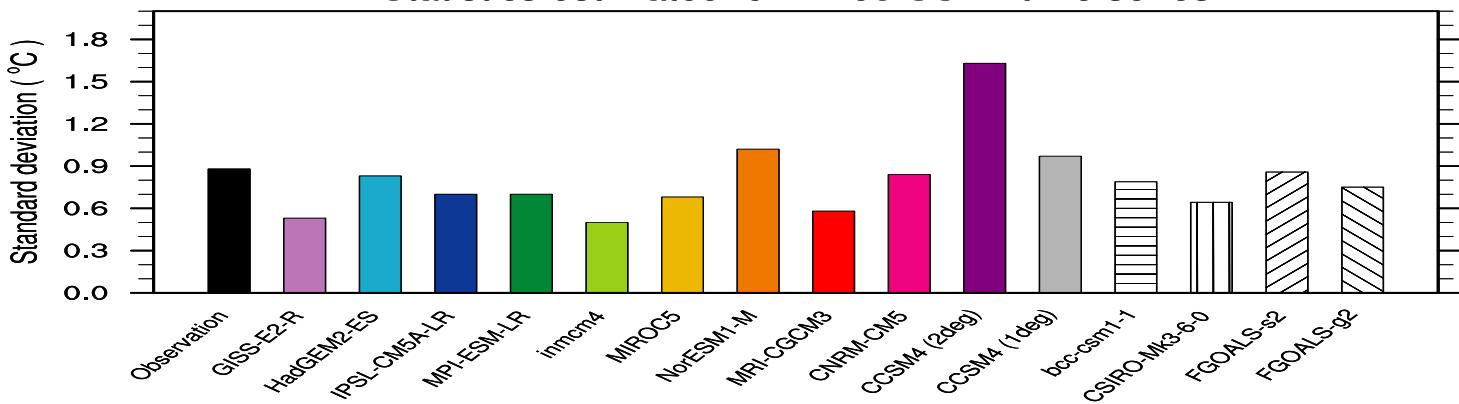
3) composite analysis of the anomaly during warm and cold periods (Zhang et al. 2009)

4) Coupled control runs from CMIP5 and corresponding AMIP runs (Taylor et al. 2012)

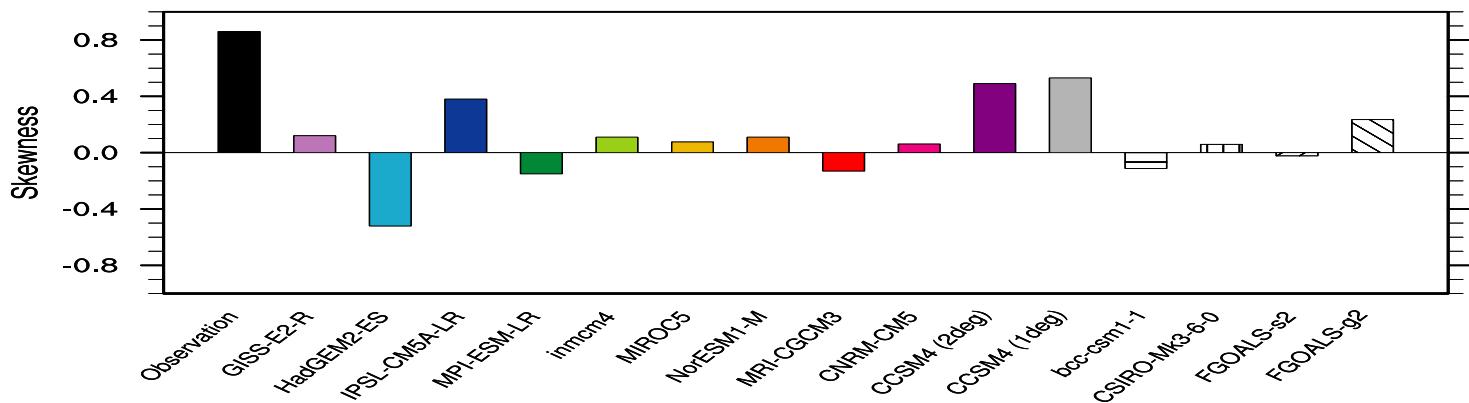
Standard deviation and Skewness of Nino3 SSTA

Statistics estimated for Nino3 SSTA time series

Standard deviation



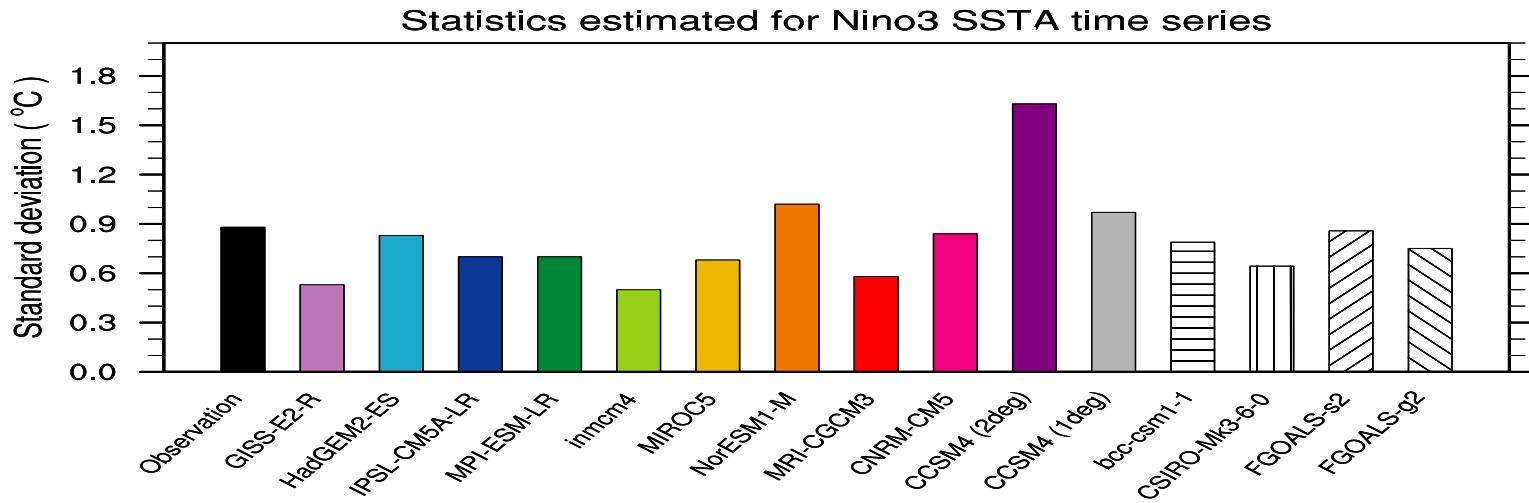
Skewness



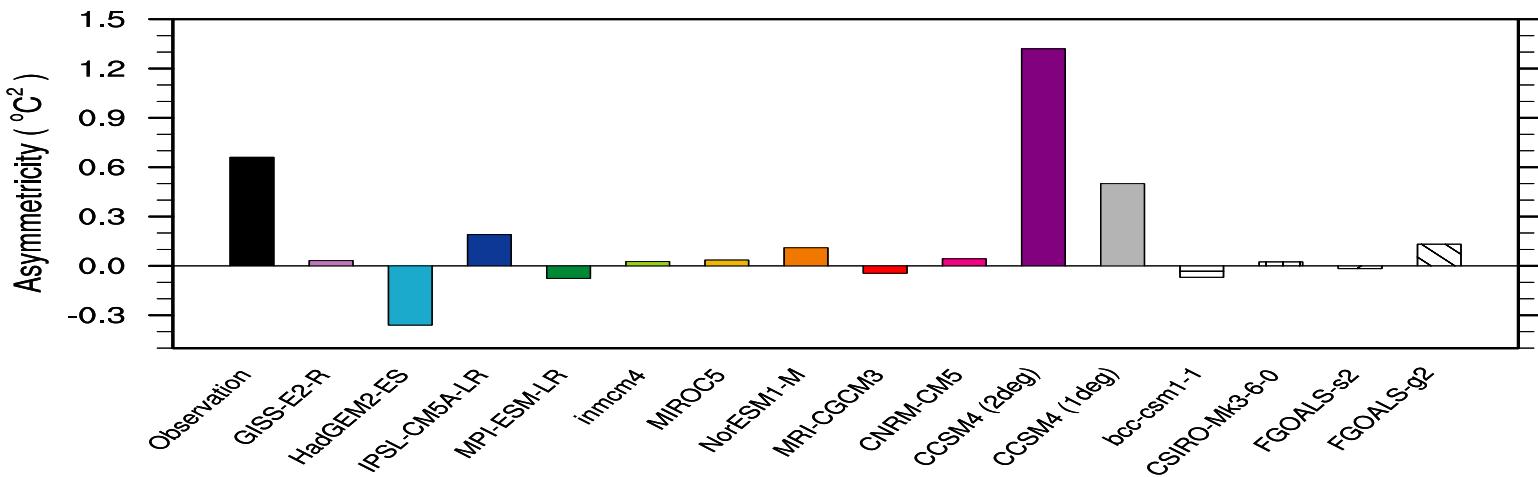
- 1) The underestimate of observed positive ENSO skewness is a common problem.
- 2) Stronger variance does not guarantee stronger skewness.

Standard deviation and asymmetry (variance weighted skewness, An et al. 2005) of Nino3 SSTA

Standard deviation

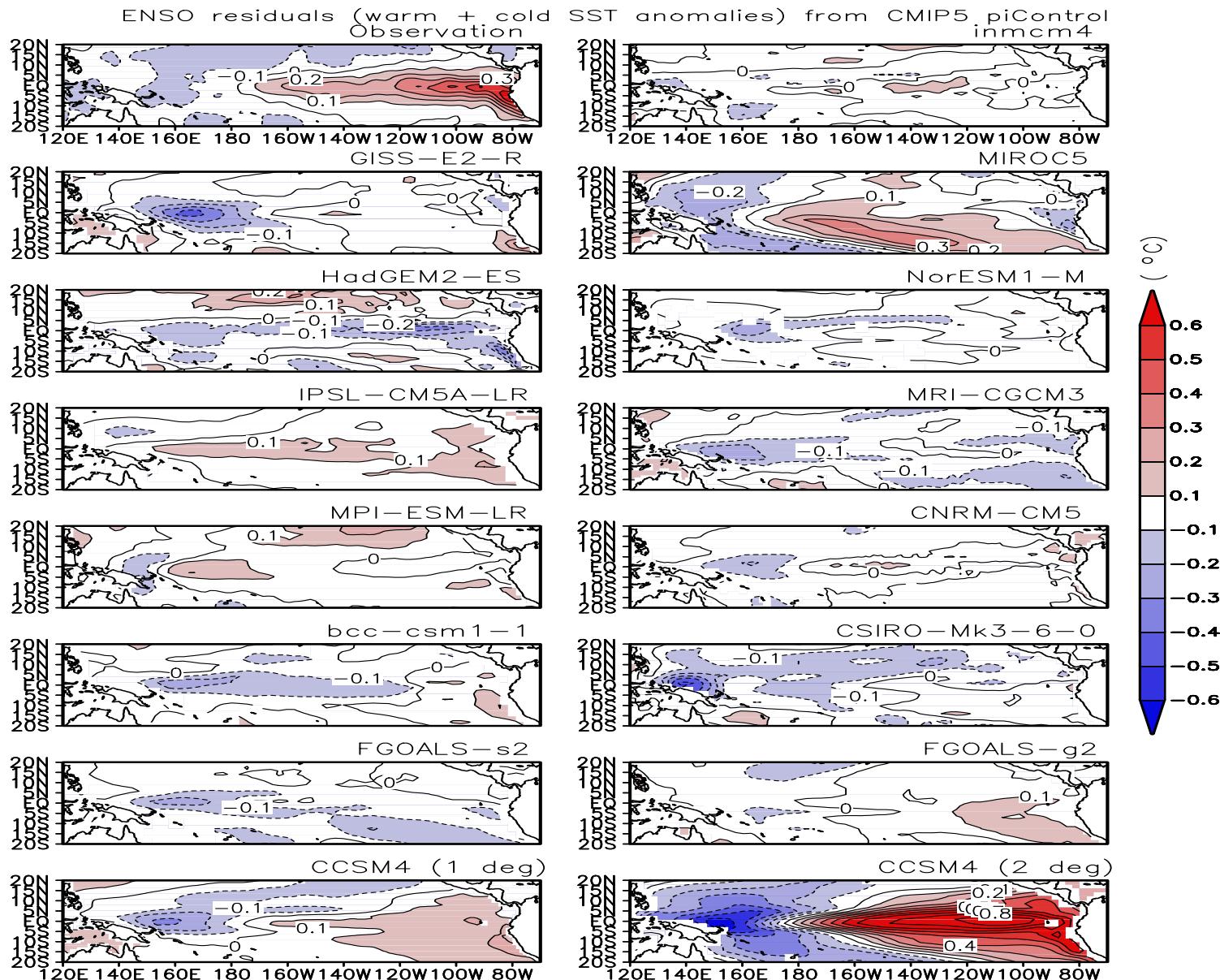


Asymmetry (variance weighted skewness, An et al. 2005)



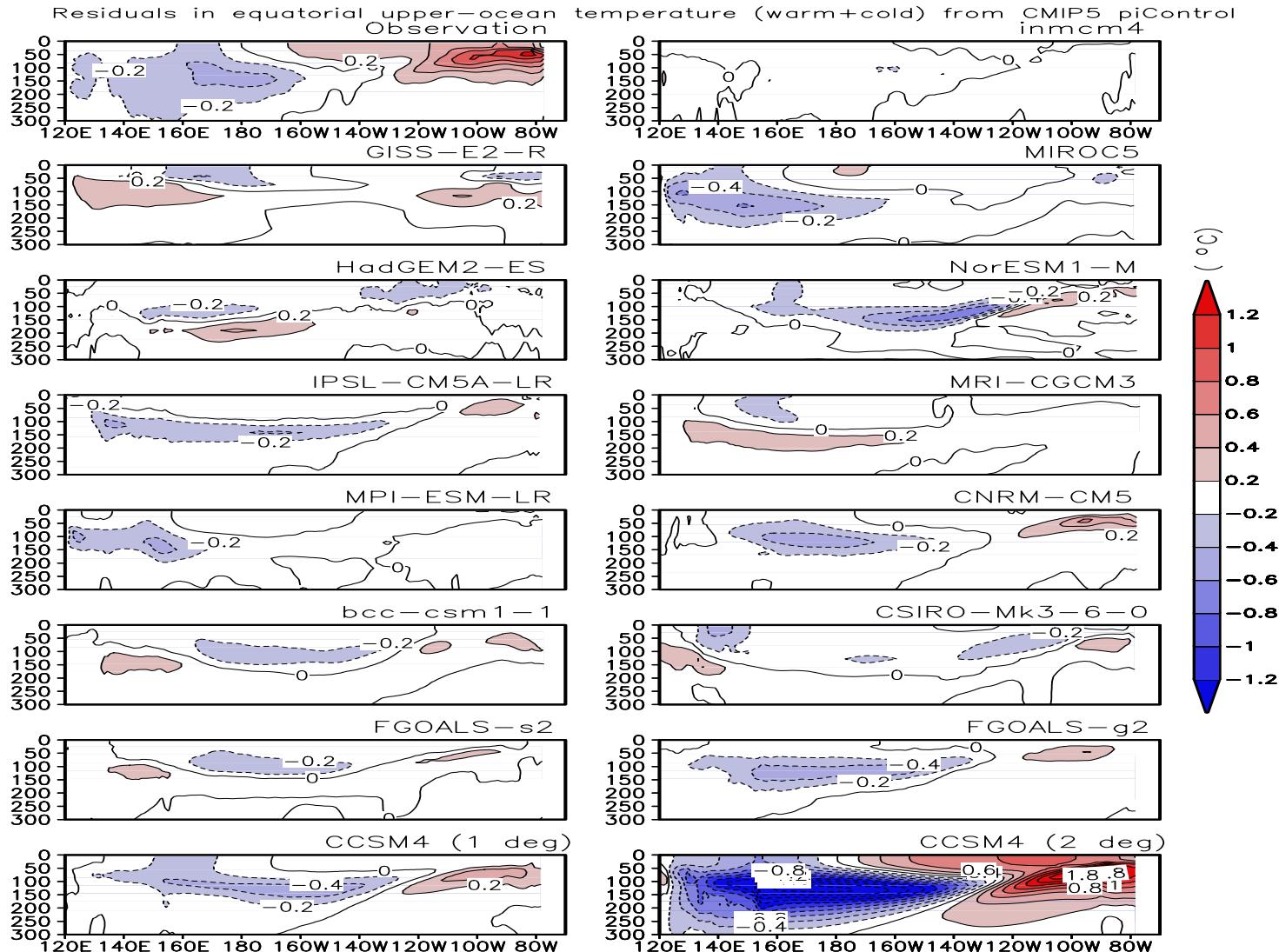
The asymmetry results are consistent with the composite analysis.

SST residuals (warm+cold)



SST residual is more consistent with SST asymmetry.

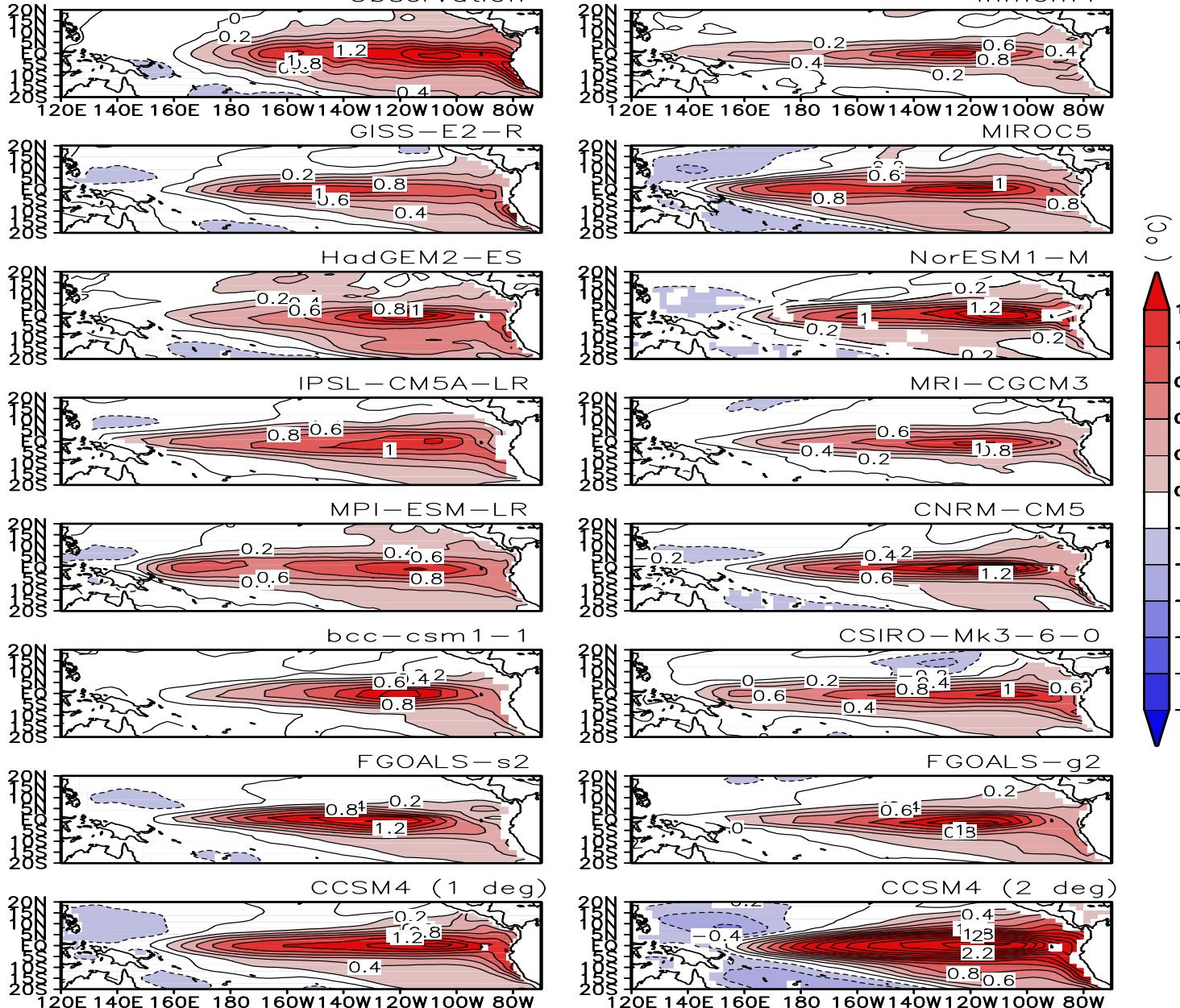
subsurface temp. residuals (warm+cold)



Consistent with SST residual, 2 deg CCSM4 has the strongest residual in subsurface temp.

Composite SST warm anomalies from CMIP5 coupled runs

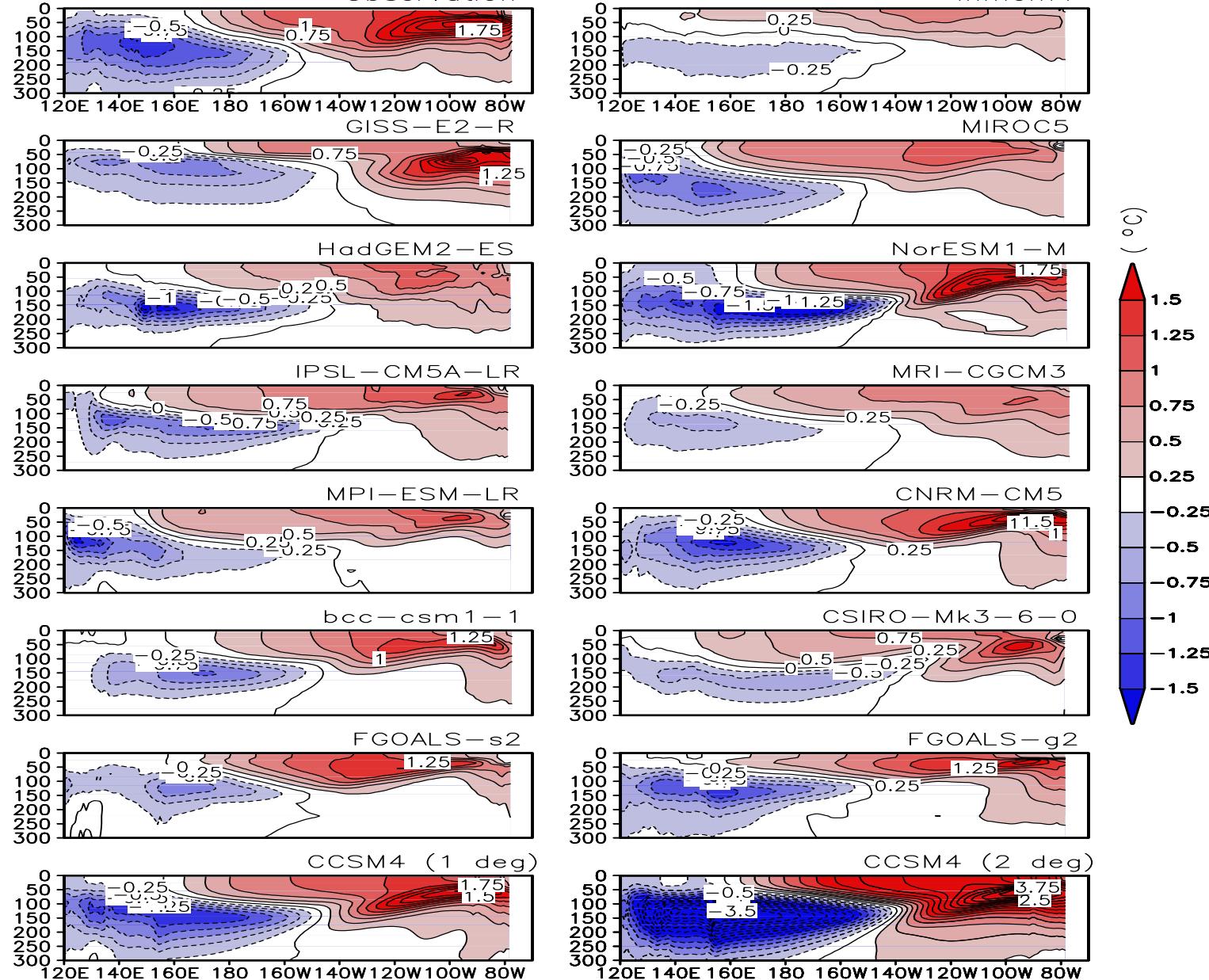
Composite SST warm anomalies from CMIP5 piControl
Observation



- 1) weaker SST warm anomalies over eastern Pacific
- 2) maximum center shifted westward

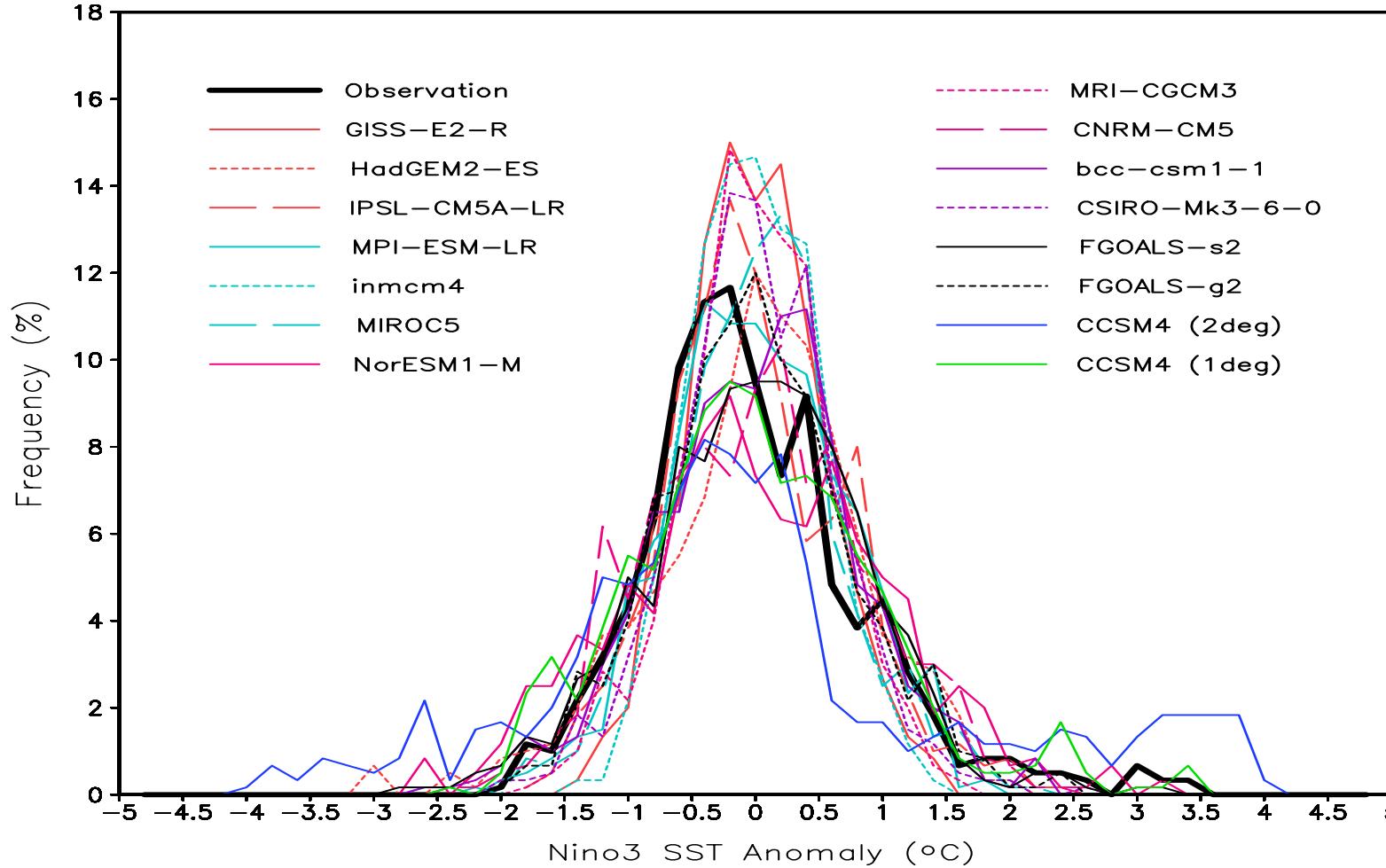
Composite subsurface temp. warm ano. from CMIP5 coupled runs

Composite equatorial upper-ocean temperature warm anomalies from CMIP5 piControl inmcm4



- 1)** Weaker warm anomalies over eastern Pacific
- 2)** maximum center shifted westward

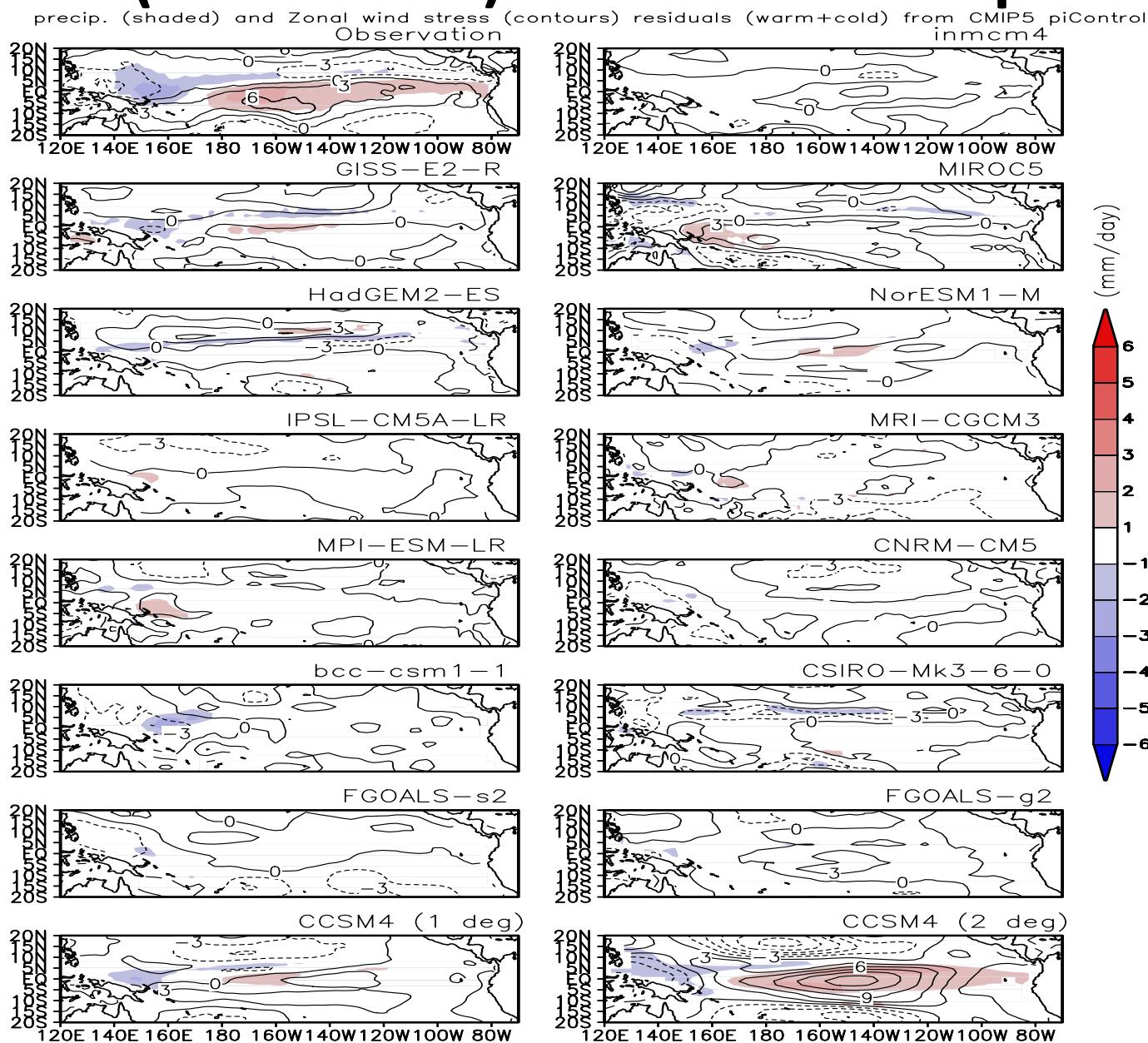
Nino3 SSTA PDF (Probability Distribution Function)



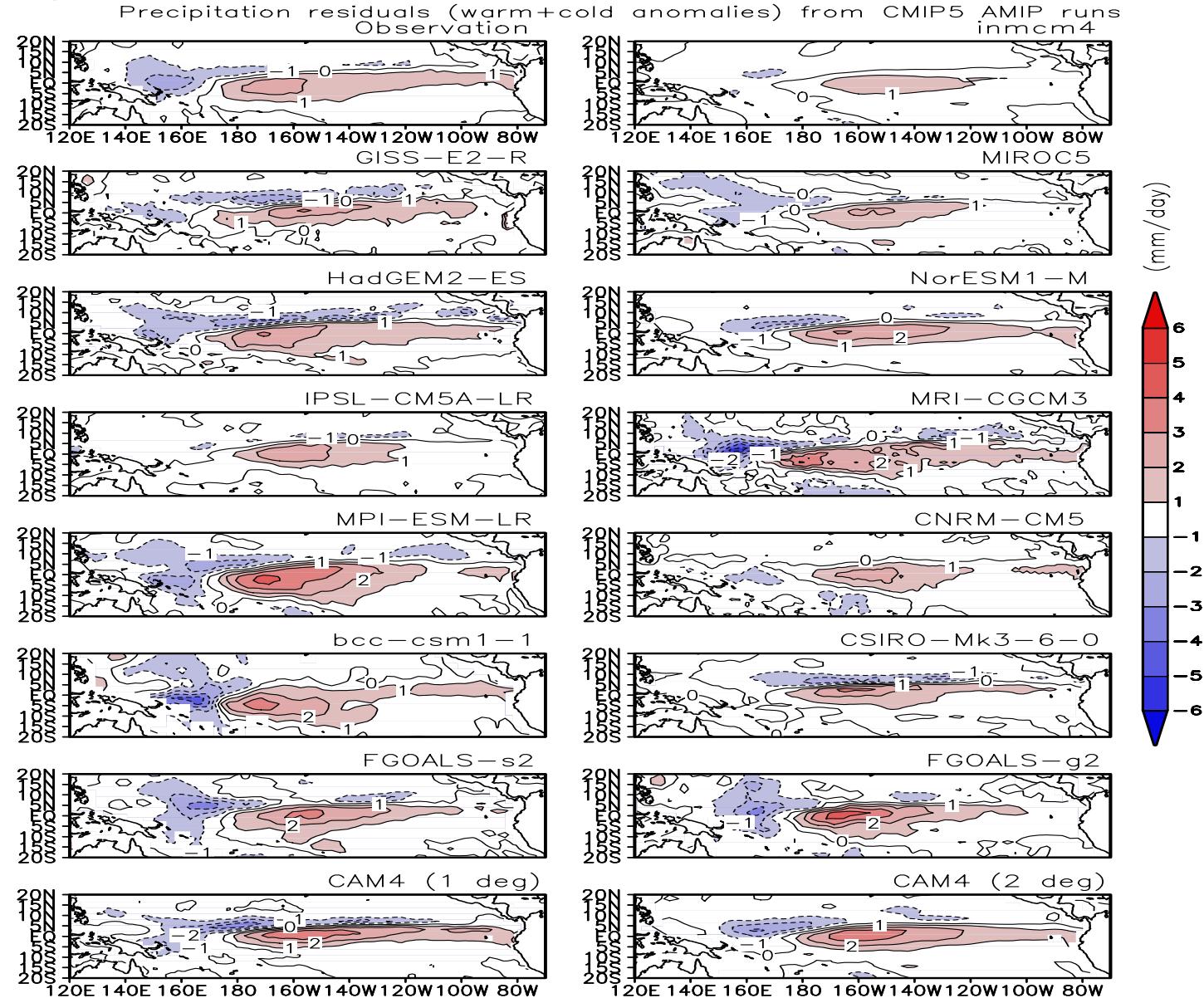
2 deg CCSM4 has a longer tail on both sides. The maximum positive (negative) anomaly can reach 4 C (-4 C) and the stronger positive anomaly is dominant.

Most models underestimate the warm anomalies and the bias for the cold phase is relatively small.

Precip. (shaded) and zonal wind stress (contours) residuals (warm+cold) from CMIP5 coupled runs



Precip. residuals (warm+cold) from CMIP5 AMIP runs

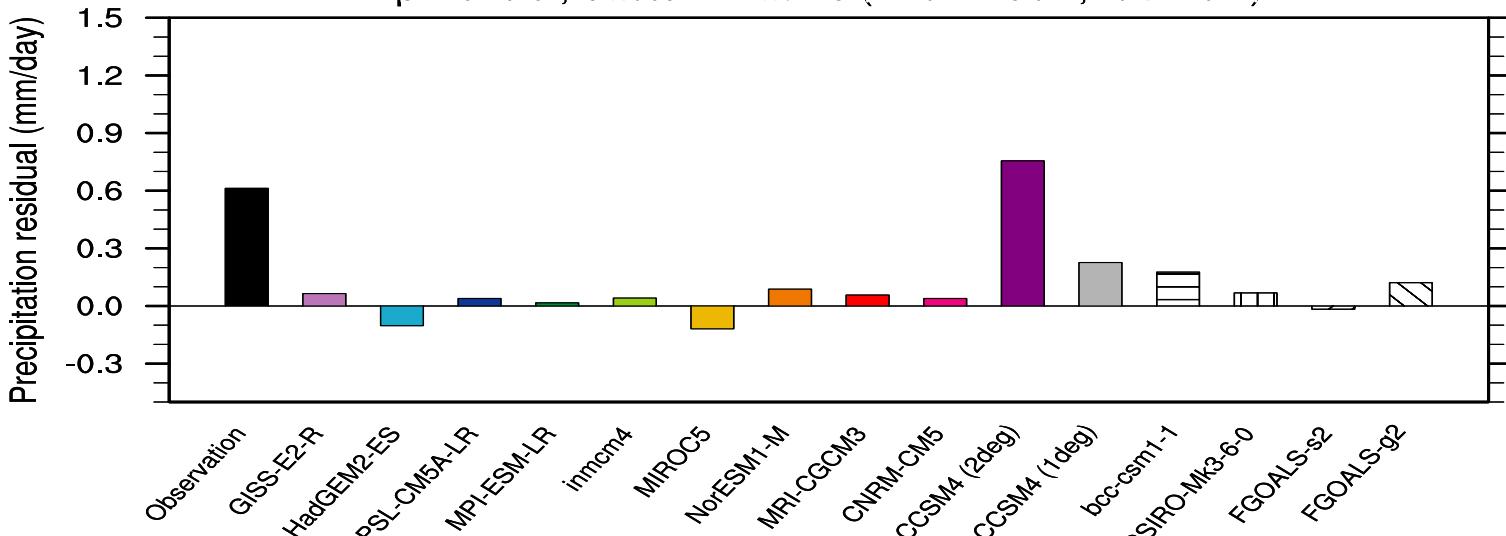


A weaker precip. asymmetry over central and eastern Pacific
(especially eastern Pacific) even forced by observed SST forcing

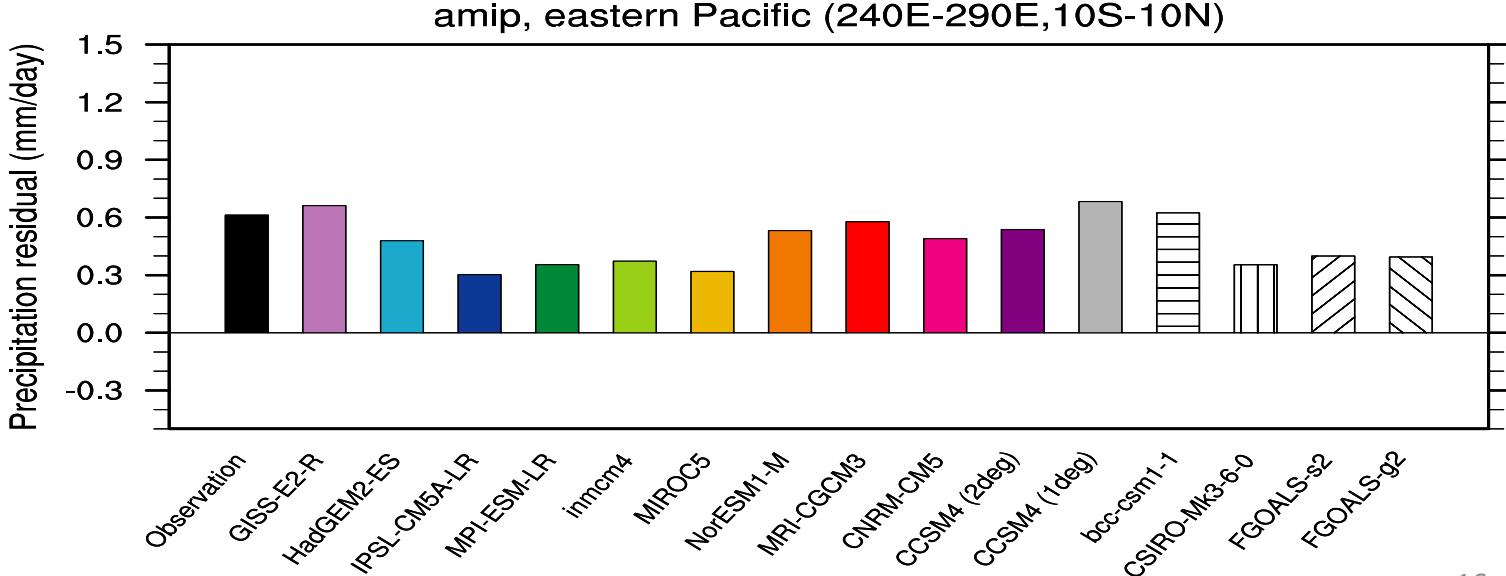
Precip. residual (warm+cold) over eastern Pacific (240E-290E, 10S-10N)

piControl, eastern Pacific (240E-290E, 10S-10N)

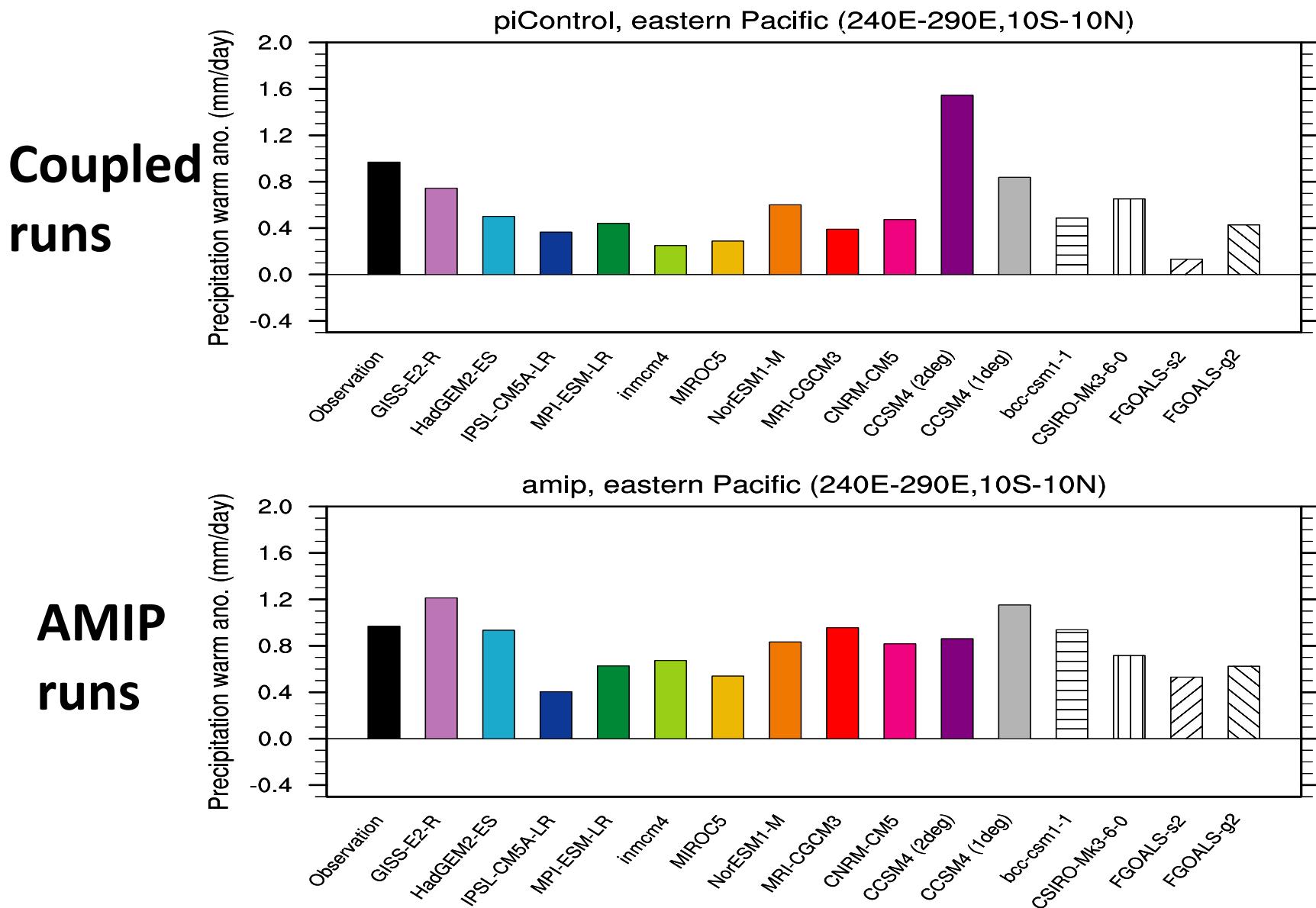
**Coupled
runs**



**AMIP
runs**



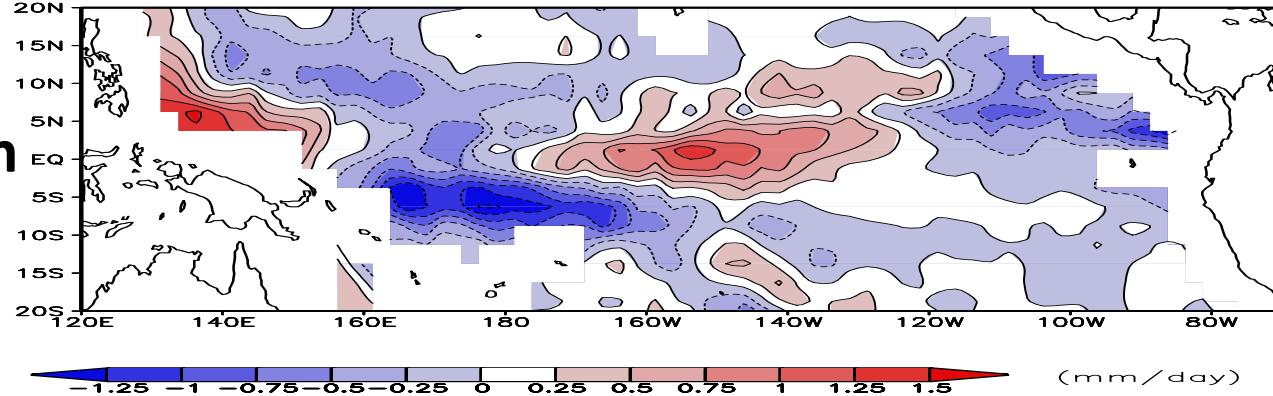
Precip. warm anomalies over eastern Pacific (240E-290E, 10S-10N)



Ensemble mean warm anomalies from AMIP (15 models)

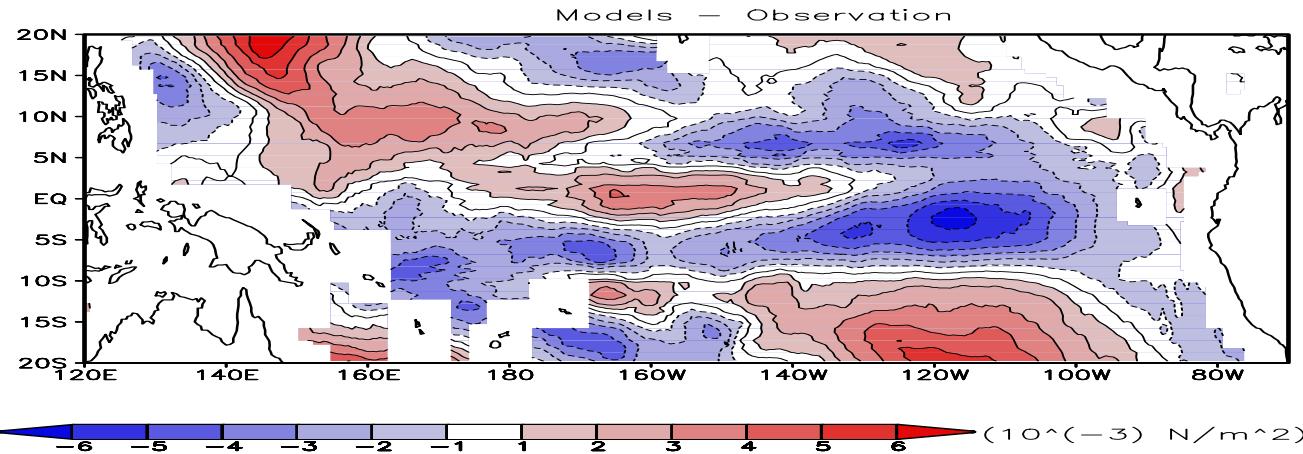
Models -OBS

ensemble mean precipitation warm anomalies from CMIP5 AMIP runs (15 models)
Models — Observation



precipitation

ensemble mean zonal wind stress warm anomalies from CMIP5 AMIP runs (15 models)
Models — Observation

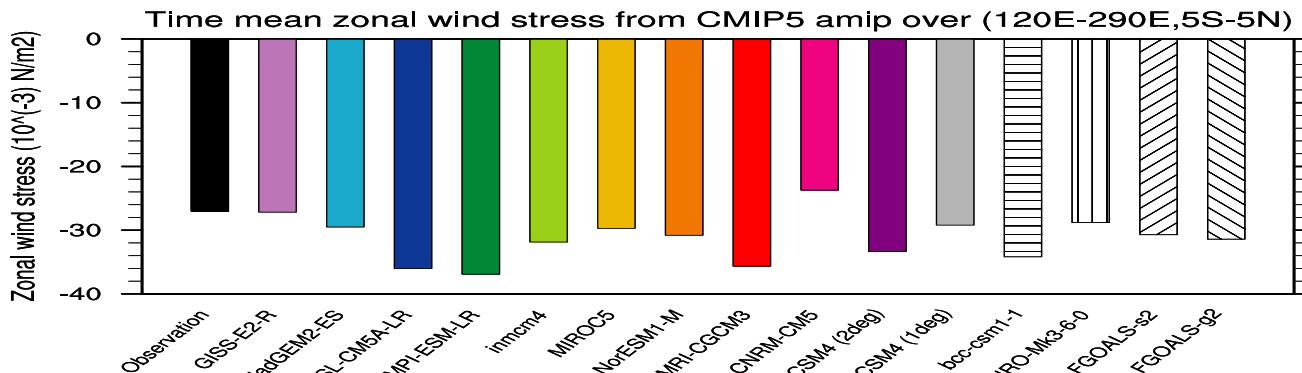


zonal wind
stress

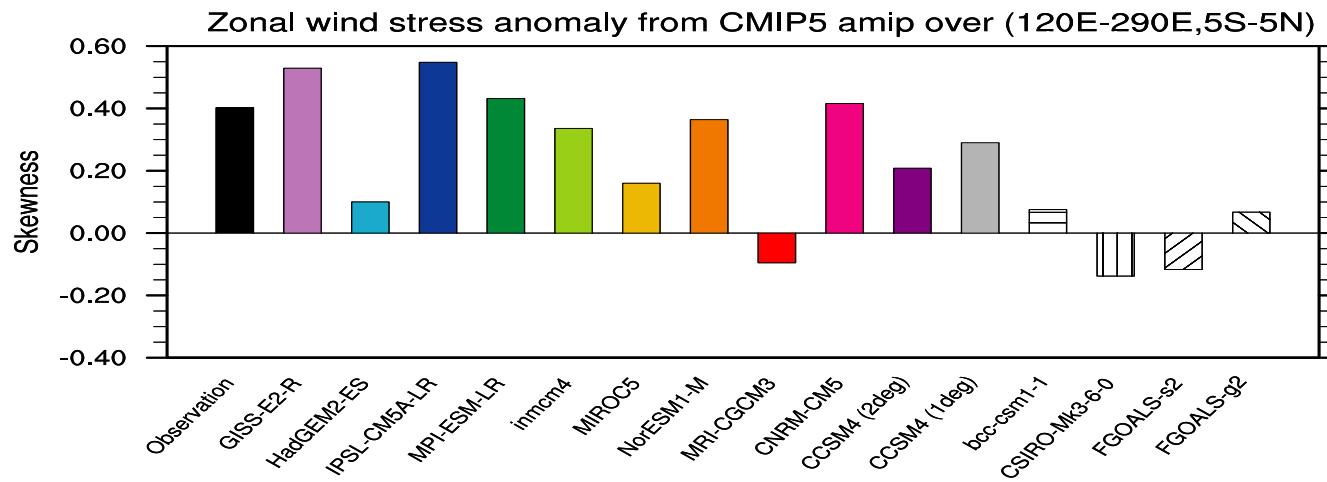
Linked to the weaker precip. response over the eastern Pacific during warm phase, the easterly winds are stronger over eastern Pacific in AMIP runs, which may contribute to the weaker warm anomaly of subsurface temp. in coupled models during warm phase.

Systematic biases in AMIP runs—Strength in the mean equatorial zonal winds and asymmetry in equatorial wind variability

Mean
equatorial
zonal wind
stress



Skewness of
equatorial
zonal wind
stress



Most models have a stronger mean equatorial zonal winds in AMIP runs.
Most models underestimate the observed positive skewness of equatorial zonal winds in AMIP runs.

Summary

- 1) Underestimate of ENSO asymmetry is a common problem in CMIP5 models.**
- 2) Stronger variance in Nino3 SST does not guarantee stronger skewness in Nino3 SST.**
- 3) Warm phase precipitation in the eastern Pacific is found to be weak across the models even in their AMIP runs.**
- 4) AMIP runs also have systematic biases in both the mean and interannual variability of the equatorial zonal winds.**

Plan to do next

- 1) Carry out forced ocean model experiments using the surface winds from the AMIP runs**

- 2) Carry out forced atmospheric model runs using symmetric SST forcing**